Announcements

- Homework for tomorrow…

  Ch. 33: CQ 1 & 2, Probs. 2 & 3

  CQ9: a) arrow @ ~45° b) arrow @ ~-45°

  32.26: a) (5.7×10^{-13} N) jhat b) (8.0×10^{-13} N) khat

  32.28: a) 1.4401×10^{6} s^{-1} b) 1.6450×10^{6} s^{-1} c) 1.6456×10^{6} s^{-1}

  32.34: (2.5×10^{-2} N), to the right

- Office hours…

  MW 10-11 am

  TR 9-10 am

  F 12-1 pm

- Tutorial Learning Center (TLC) hours:

  MTWR 8-6 pm

  F 8-11 am, 2-5 pm

  Su 1-5 pm

Chapter 33

Electromagnetic Induction

(*Induced Currents & Motional emf*)

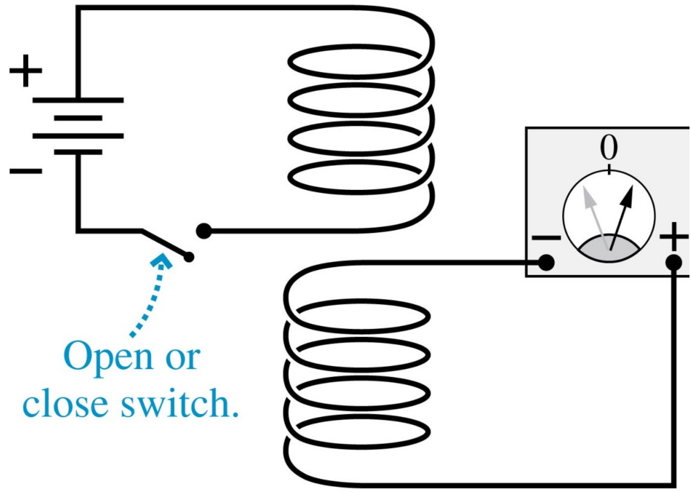
Last time…

- Torque on a current loop in a *B*-field

$$\boxed{\vec{\tau} = \vec{\mu} \times \vec{B}}$$

33.1
Induced Currents

Michael Faraday's discovery of 1831..



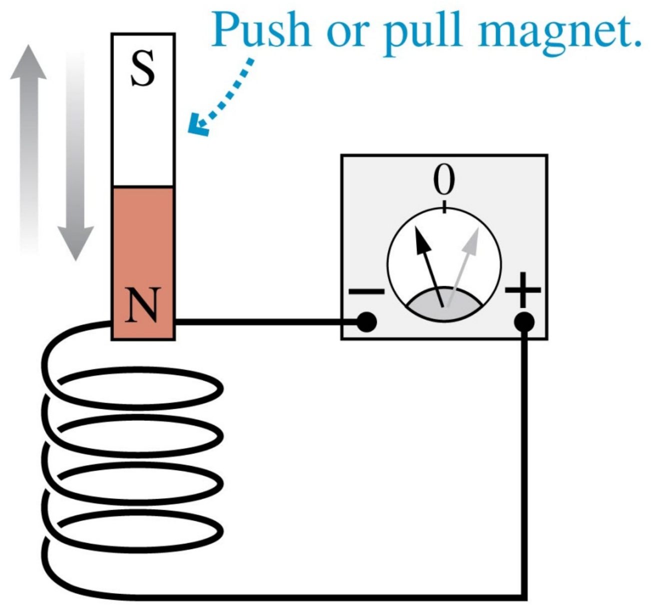
- When one coil is placed directly above another, there is NO current in the lower circuit while the switch is in the closed position.

- A *momentary* current appears whenever the switch is *opened* or *closed.*

33.1
Induced Currents

Michael Faraday's discovery of 1831..

- When a bar magnet is *pushed into* a coil of wire, it causes a *momentary deflection* of the current-meter needle.
- Holding the magnet inside the coil has NO effect.
- A quick *withdrawal* of the magnet *deflects* the needle in the other direction.



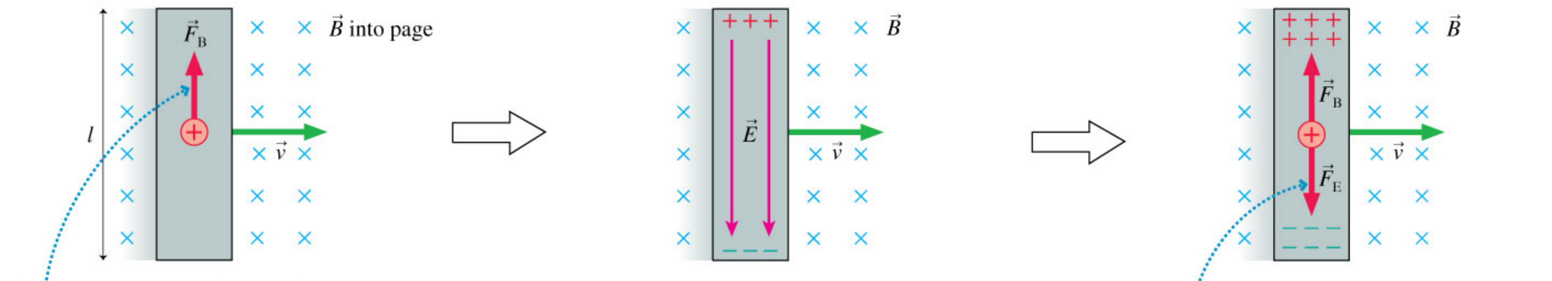
33.1
Induced Currents

Michael Faraday's discovery of 1831..

Faraday found that there IS a current in a coil of wire *if and only if* the *B*-field passing through the coil is *changing*!

33.2
Motional emf

Consider a conductor of length l that moves with velocity v through a *perpendicular uniform B*-field…



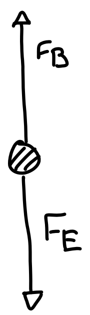
Charge carriers in the wire experience an upward force of magnitude $F_B = qvB$. Being free to move, positive charges flow upward (or, if you prefer, negative charges downward).

The charge separation creates an electric field in the conductor. $\vec{E}$ increases as more charge flows.

The charge flow continues until the downward electric force $\vec{F}_E$ is large enough to balance the upward magnetic force $\vec{F}_B$. Then the net force on a charge is zero and the current ceases.

What is the *motional emf*?

Charge seperation will increase until



$$F_B = F_E$$

$$qvB = qE$$

$$E = vB$$

The electric potential difference is ....

$$\Delta V = -\int_1^2 \vec{E}\cdot d\vec{s}$$

$$\vec{E} = -vB\hat{j}\ ,\ d\vec{s} = dy\,\hat{j}$$

$$\vec{E}\cdot d\vec{s} = -vB\,dy$$

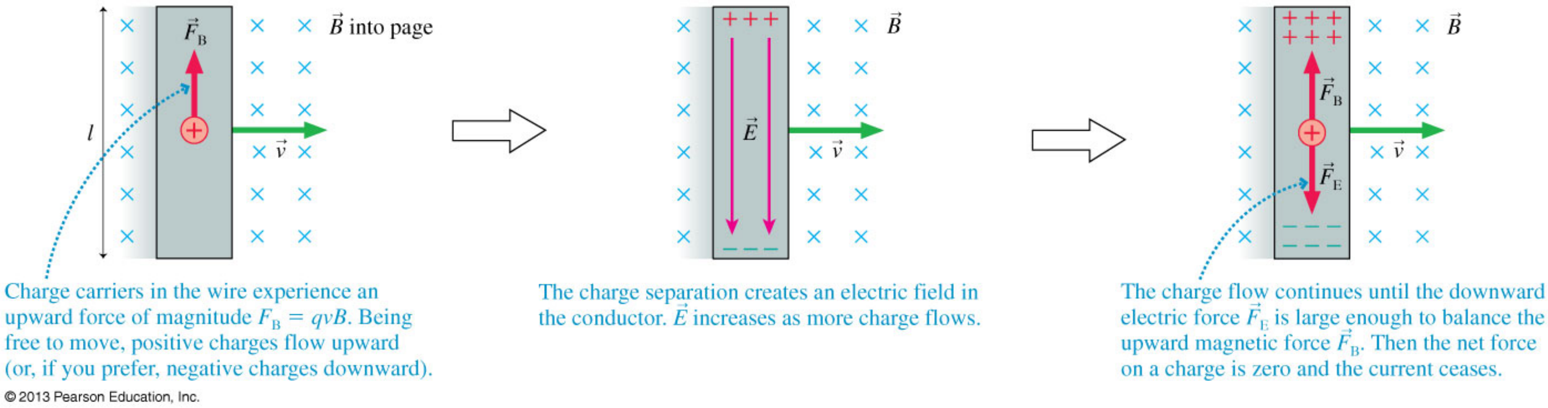
$$V_{Top} - V_{Bottom} = -\int_0^l -vB\,dy = vB\int_0^l dy$$

$$= vBl$$

$$\mathcal{E} = vBl$$

33.2
Motional emf

Consider a conductor of length *l* that moves with velocity *v* through a *perpendicular uniform B*-field…



What is the *motional emf*?

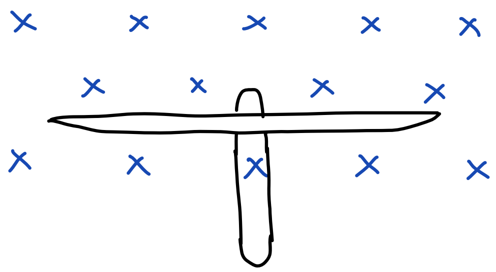
$$\boxed{\mathcal{E} = vlB}$$

The motion of the conductor through a *B*-field *induces* a *potential difference* between the ends of the conductor!

i.e. 33.1
Measuring the earth's *B*-field

It is known that the earth's *B*-field over northern Canada points straight down. The crew of a Boeing 747 aircraft flying at 260 m/s over northern Canada finds a 0.95 V potential difference between the wing tips. The wing span of a Boeing 747 is 65 m.

What is the *B*-field strength there?



$\mathcal{E} = vB\ell$

$\mathcal{E} = 0.95V$

$v = 260\,m/s$

$\ell = 65m$

$B = \dfrac{\mathcal{E}}{v\ell}$

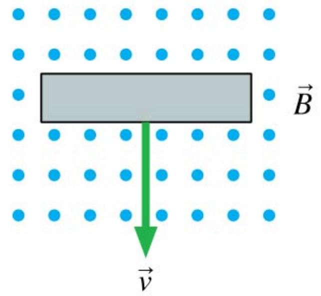
$= \dfrac{0.95V}{260m/s(65m)}$

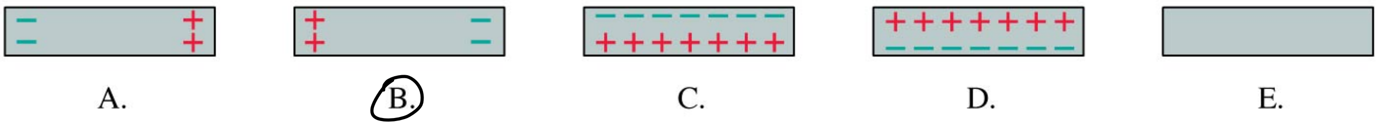
$B = 5.6\times10^{-5}\,T$

Quiz Question 1

A metal bar moves through a B-field. The induced charges on the bar are

V×B

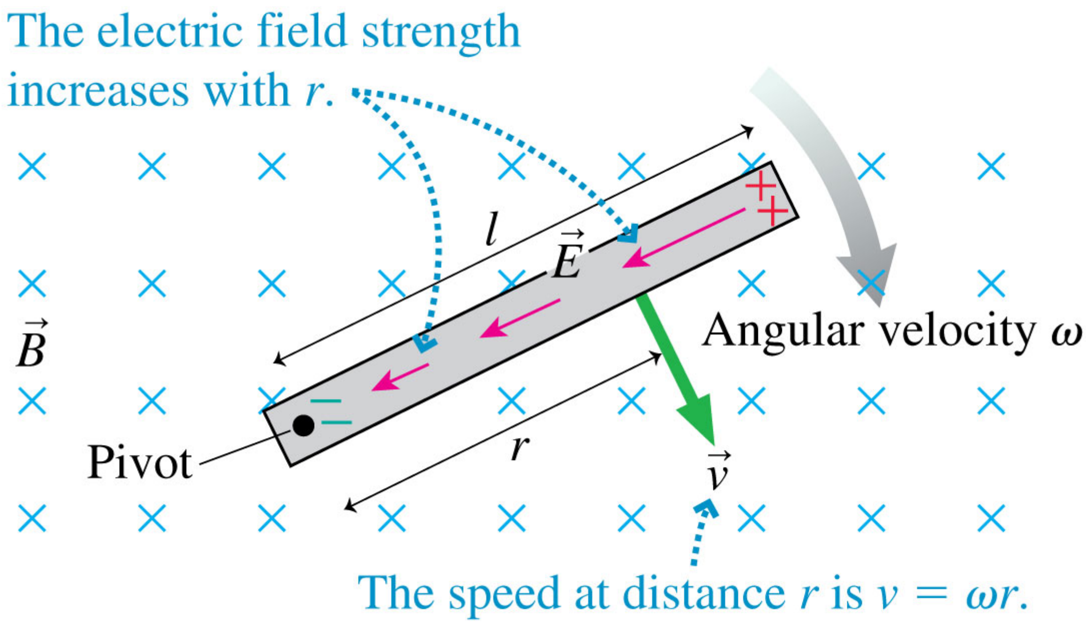




i.e. 33.2
Potential difference along a rotating bar

A metal bar of length l rotates with angular velocity ω about a pivot at one end of the bar. A uniform B-field is perpendicular to the plane of rotation.

What is the *potential difference* between the ends of the bar?



$$\Delta V = -\int \vec{E}\cdot d\vec{s}$$

$\vec{E} = -vB\hat{e}_r$ $\quad$ $\vec{E}\cdot d\vec{s} = -vBdr$ $\quad$ $v = \omega r$

$d\vec{s} = dr\,\hat{e}_r$ $\quad$ $= -\omega Br\,dr$

$$-\int_0^l -\omega Br\,dr = \omega B\int_0^l r\,dr = \tfrac{1}{2}\omega Br^2\Big|_0^l$$

$v_{mid} = \frac{1}{2}\omega l$

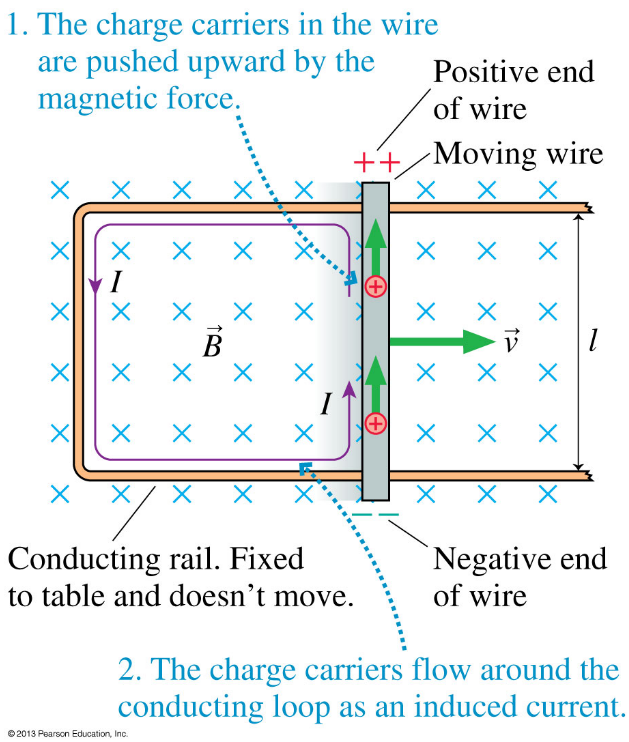
$$\mathcal{E} = \tfrac{1}{2}\omega Bl^2$$

$$\mathcal{E} = v_{mid}Bl$$

Induced Current in a Circuit…

Consider a wire sliding with speed v along a U-shaped conducting rail..

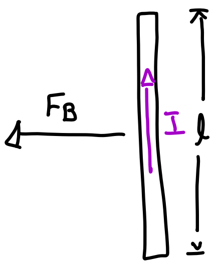
What is the *induced current* in the circuit?



What is the *force* required to pull the wire with a constant speed v?

Induced current

$$\frac{\mathcal{E}}{R} = I = \frac{vlB}{R}$$



$$F_B = IlB = \frac{vlB}{R}\, lB = \frac{vl^2B^2}{R}$$

Induced Current in a Circuit…

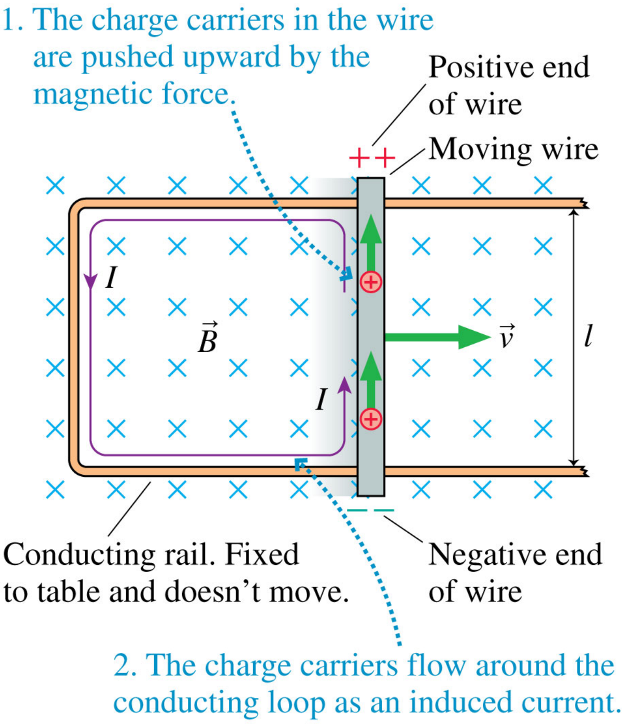
Consider a wire sliding with speed v along a U-shaped conducting rail..

What is the *induced current* in the circuit?

$$I = \frac{vlB}{R}$$

What is the *force* required to pull the wire with a constant speed v?

$$F_{pull} = F_{mag} = \frac{vl^2B^2}{R}$$



Energy Considerations…

What happens to the energy transferred to the wire by this work?

Is energy *conserved* as the wire moves along the rail?

Energy

Consider the power exerted by the pushing or pulling force

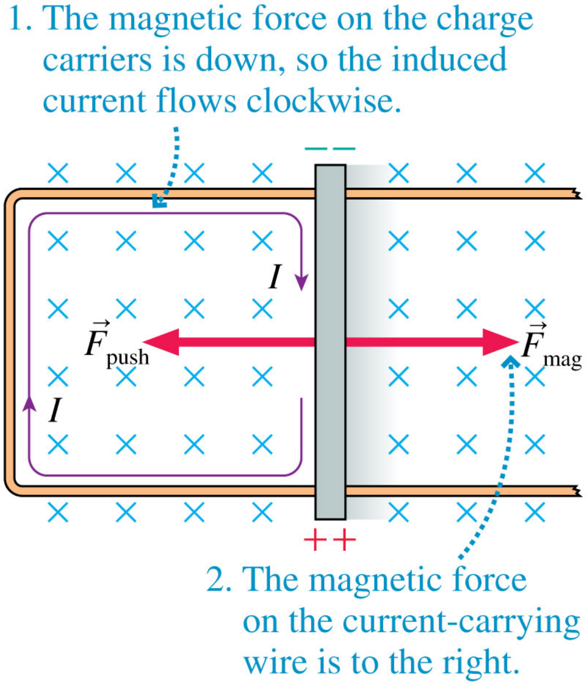
$$P_{input} = FV = \frac{v^2 \ell^2 B^2}{R}$$

Power Dissipated ?

$$P_{Dis} = I^2 R$$

$$= \frac{v^2 \ell^2 B^2}{R^2} R = \frac{v^2 \ell^2 B^2}{R}$$

$$P = \frac{v^2 \ell^2 B^2}{R}$$

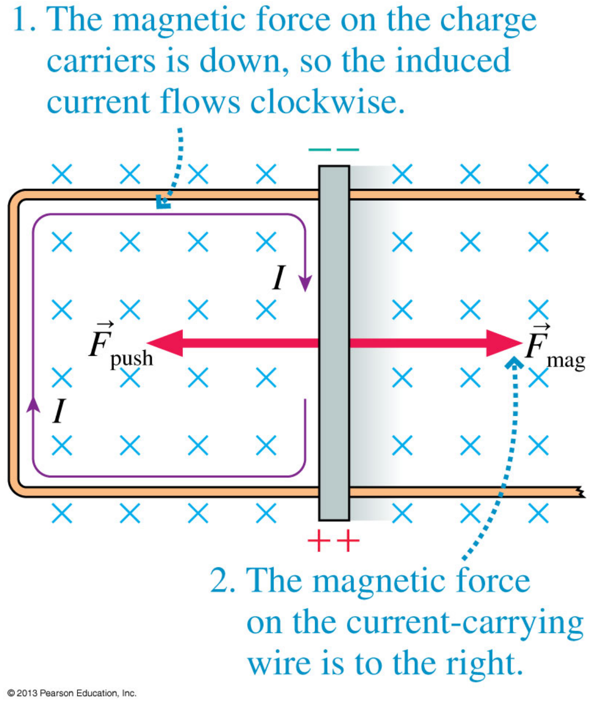


Energy Considerations…

What happens to the energy transferred to the wire by this work?

Is energy *conserved* as the wire moves along the rail?

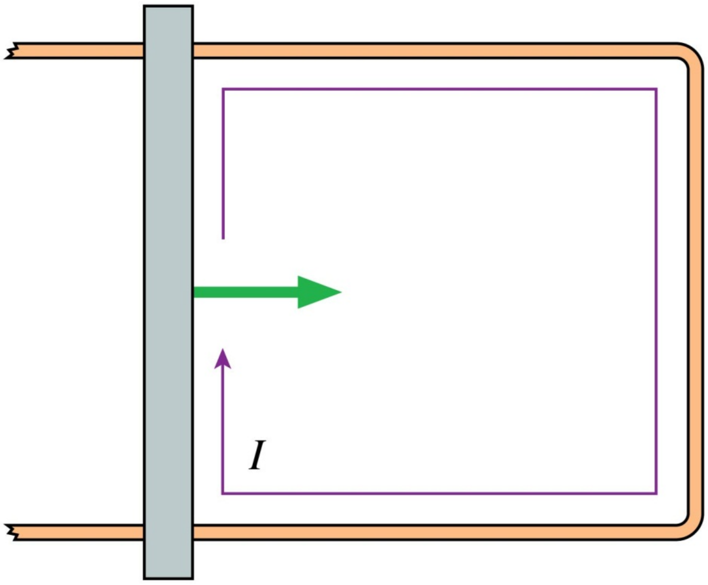
$$\boxed{P_{input} = P_{dis} = \frac{v^2 l^2 B^2}{R}}$$



The *rate* at which *work is done* on the circuit *exactly equals* the *rate* at which *energy is dissipated.*

Quiz Question 2

An induced current flows clockwise as the metal bar is pushed to the right. The *B*-field points



1. up.
2. down.
3. into the screen.
4. out of the screen.
5. to the right.